EFFECTS OF PRESCRIBED FIRE ON CONDITIONS INSIDE A CUBAN PARROT (*AMAZONA LEUCOCEPHALA*) SURROGATE NESTING CAVITY ON GREAT ABACO, BAHAMAS

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ABSTRACT.—Cuban Parrots (*Amazona leucocephala*) on the island of Great Abaco in the Bahamas forage and nest in native pine forests. The population is unique in that the birds nest in limestone solution holes on the forest floor. Bahamian pine forests are fire-dependent with a frequent surface fire regime. The effects of fire on the parrots, especially while nesting, are not well known. We measured ambient conditions inside a cavity characteristic of the Cuban Parrot's Abaconian population as a prescribed fire passed over it. Cavity conditions were relatively benign; although temperatures immediately outside the cavity rose to >800° C, inside temperatures increased only 5° C at 30 cm inside the entrance and 0.4° C at the cavity floor (cavity depth was ~120 cm). CO_2 levels briefly rose to 2,092 ppm as the flames passed, but dropped to nearly ambient levels approximately 15 min later. Smoke levels also were elevated only briefly, with 0.603 mg of total suspended particulates filtered from 0.1 m^3 of air. Smokey conditions lasted approximately 20 min. *Received 23 September 2005, accepted 5 May 2006.*

In the Bahamas, the Cuban Parrot (*Amazona leucocephala*) currently occurs only on the islands of Great Abaco and Great Inagua. The Bahamian populations of Cuban Parrots are often recognized as a subspecies (*Amazona leucocephala bahamensis*). Regardless of taxonomic rank, the Great Abaco population is distinct because the parrots nest in the ground, exploiting small solution holes in the exposed limestone bedrock found in stands of Caribbean pine (*Pinus caribaea* var. *bahamensis*)—a forest type known locally as "pineyards." This ground-nesting behavior is unique, as all other populations of Cuban Parrots are known to nest in tree cavities. Pine seeds and fruit of other pineyard plants are important food sources for the parrots on Great Abaco during the breeding season (Attrill 1981, Snyder et al. 1982). Bahamian pineyard ecosystems are fire-dependent: frequent fires suppress competing broad-leaved vegetation, remineralize nutrients bound in litter, and prevent fuel buildups that increase the risk of greater fire intensity when accidental fires occur. In the absence of fire, broad-leaved forest species eventually outcompete and replace the overstory pines. In analogous pine forests in southern Florida, suppression of fire resulted in forest succession to broad-leaved vegetation in as few as 25 years (Robertson 1955, Loope and Dunevitz 1981). Fires have been occurring in Great Abaco pineyards every 3 to 5 years since at least the late 1700s (H. D. Grissino-Mayer unpubl. data). Human activities are currently the most frequent sources of ignition, although lightning-ignited fires do occur and their frequency is probably underestimated.

Prescribed fire has become a popular management tool in many protected areas containing fire-dependent vegetation. Currently, the extemporaneous fire management practiced by local Abaconians has been very effective in maintaining the pineyards. Future fire management in the Bahamas will likely depend more on prescribed fires lit by trained professionals as land-use changes complicate fire-management situations. The judicious application of prescribed fire as a resource management tool requires knowledge of fire impacts, both direct and indirect, on ecosystem properties. Although the relationship between fire and pineyard vegetation is relatively clear, the impact of fire on pineyard wildlife, especially parrots, is not as well known. The ground-nesting behavior of the Abaconian

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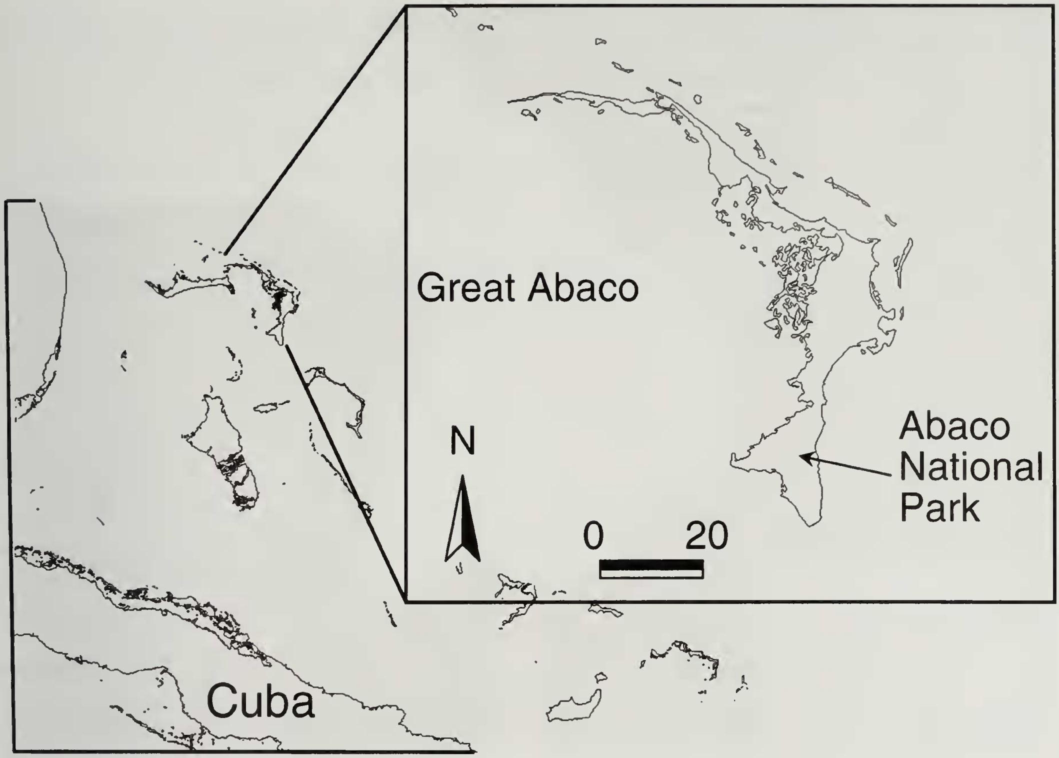

FIG. 1. Location of the island of Great Abaco and Abaco National Park within the Commonwealth of the Bahamas.

population raises several important questions regarding the ways in which fires might affect nesting parrots.

Fire can impact parrots both indirectly and directly. Indirect effects are mediated primarily through vegetation and subsequent impacts on parrot food resources and nesting cover. Direct effects would likely be most important during the nesting season. A passing fire might result in increased temperatures, smoke, and CO_2 levels inside the nesting cavity that could stress or kill parrot nestlings or adults reluctant to abandon the nest. Herein, we report the ambient conditions inside a limestone cavity characteristic of Cuban Parrot nest sites as a prescribed fire passed over it. Conditions are reported as means ± SD.

METHODS

The study site bordered Abaco National Park (ANP; 26° 2′ N, 77° 15′ W) in the southern portion of the island of Great Abaco, Bahamas (Fig. 1). ANP was established in 1994 by The Bahamas National Trust and encompasses 8,300 ha. The habitat consists of pineyard vegetation along with some tropical dry forest known locally as "coppice." A forest inventory we conducted in the vicinity of the experimental area revealed that pine trees now occupying the park are growing in even-aged stands. Mean tree height was 16 m ± 0.6, mean diameter at breast height was 18.6 cm ± 1.81, and mean density was 364 ± 273 trees/ha.

On 31 October 2004, a crew led by personnel of The Nature Conservancy lit a prescribed fire in Abaco National Park as a training exercise for Bahamian fire fighters and resource managers. The crew used drip torches to ignite the fire at 13:00 EST under moderate weather conditions: ~1 m/sec wind speed, 56% relative humidity, and high levels of fuel moisture resulting from rainfall the previous evening. The area burned was a ~10 ha block bounded by former logging roads and a highway. Although the site's exact fire history was unknown, fuel loads were typical of areas that had not burned for about 3 yr. The study plot was embedded in an area of high-density parrot nesting activity (Gnam and Burchsted 1991, Stahala 2005), with an active colony <1 km distant. The fuel loads and stand structure in both the study area and the nearby colonies were similar.

Prior to ignition in the area to be burned, we located a solution hole characteristic of those used by parrots as nesting cavities (Snyder et al. 1982, Gnam 1990). This cavity entrance was ~30 cm in diameter, within the diameter range previously reported for parrot cavity entrances, and was approximately 120 cm deep, also within the range reported for parrot cavities (124.2 ± 55.4; Gnam 1990). The floor was dry and contained a small heap of dried grass—evidence of vertebrate activity within the cavity. In order to measure temperatures inside the cavity, we placed two type-T thermocouples read by Hobo dataloggers (Hobo Pro Series, Onset, Inc., Bourne, Massachusetts) on the cavity floor, and suspended another thermocouple 30 cm inside the entrance. As the fire passed over the cavity, an infrared camera (S60, FLIR, Inc., Wilsonville, Oregon) was used to measure ground surface temperatures outside the cavity.

Inside the cavity, we also measured CO_2 concentration and total suspended particulate density by sampling air through a 4-m-long, 5-mm-diameter copper tube with the end placed 10 cm above the surface of the cavity floor. A particulate matter (PM) 2.5 filter (collects particulate matter ≥2.5 μm) was attached to the tube tip inside the cavity. At its other end, the tube was connected to an air pump set at a maximum flow rate of 1.5 l/min. We measured CO_2 levels with an infrared gas analyzer (EGM4, PP Systems, Inc., Amesbury, Massachusetts); the air flow rate was measured simultaneously with a mass flow controller (Top-Trak 822-OV1-PV1-V1, Sierra Instruments, Inc., Monterey, California). The output of the gas analyzer and mass flow controller were measured every second and stored as 1-min averages by a datalogger (CR10X, Campbell Scientific, Inc., Logan, Utah). All instruments were placed in a small plastic enclosure. To prevent fire damage, we raked fuel from around the enclosure, then covered it with a U.S. Department of Agriculture Forest Service fire shelter, an aluminized fiberglass tent designed to shield an entrapped firefighter from radiant energy.

RESULTS

Although a variety of ignition techniques were employed in the area, a low-intensity backing fire arrived at the cavity area at approximately 15:14. The low fuel loads found in the area, coupled with the moderate weather conditions, created short flames (~30 cm high) and a slow rate of spread; the fireline crept along at about 15 cm/min as the fire passed the vicinity of the cavity entrance. The residence time of the fire within 1 m of the cavity entrance was ~15 min. The maximum fire temperature recorded outside the cavity entrance was 803° C. We observed minor temperature changes inside the cavity as the fire passed: a 5° C increase occurred 30 cm inside the entrance, and a 0.4° C increase occurred at the cavity floor (Fig. 2A).

A total of 0.903 mg of suspended particulates was captured on the PM 2.5 air filter after 0.1 m^3 of air had been filtered. Changes in air flow through the filter indicated that smoke accumulation was constant for a brief period, causing a steep, linear decrease in air flow, but then smoke concentration declined toward an asymptote (Fig. 2B). There was little lingering smoke production, as almost no smoldering occurred following passage of the flaming front.

CO_2 levels in the cavity rose sharply when the fire approached the entrance and then dropped sharply as the fire moved past (Fig. 2B). The maximum concentration recorded was 2,092 ppm. Concentrations of CO_2 >2,000 ppm occurred for 5 min, and concentrations >1,000 ppm occurred for 19 min.

DISCUSSION

We observed relatively benign conditions inside the cavity as the fire passed. The magnitude of temperature change caused by the fire was similar to that observed during a typical diurnal cycle in the absence of fire (GPM unpubl. data). Inside the cavity, smoke levels were low, and CO_2 levels rose moderately, but declined quickly as the fire passed. The CO_2 concentrations we observed probably would not have had much effect on parrots: although data on CO_2 effects on birds were not avail-

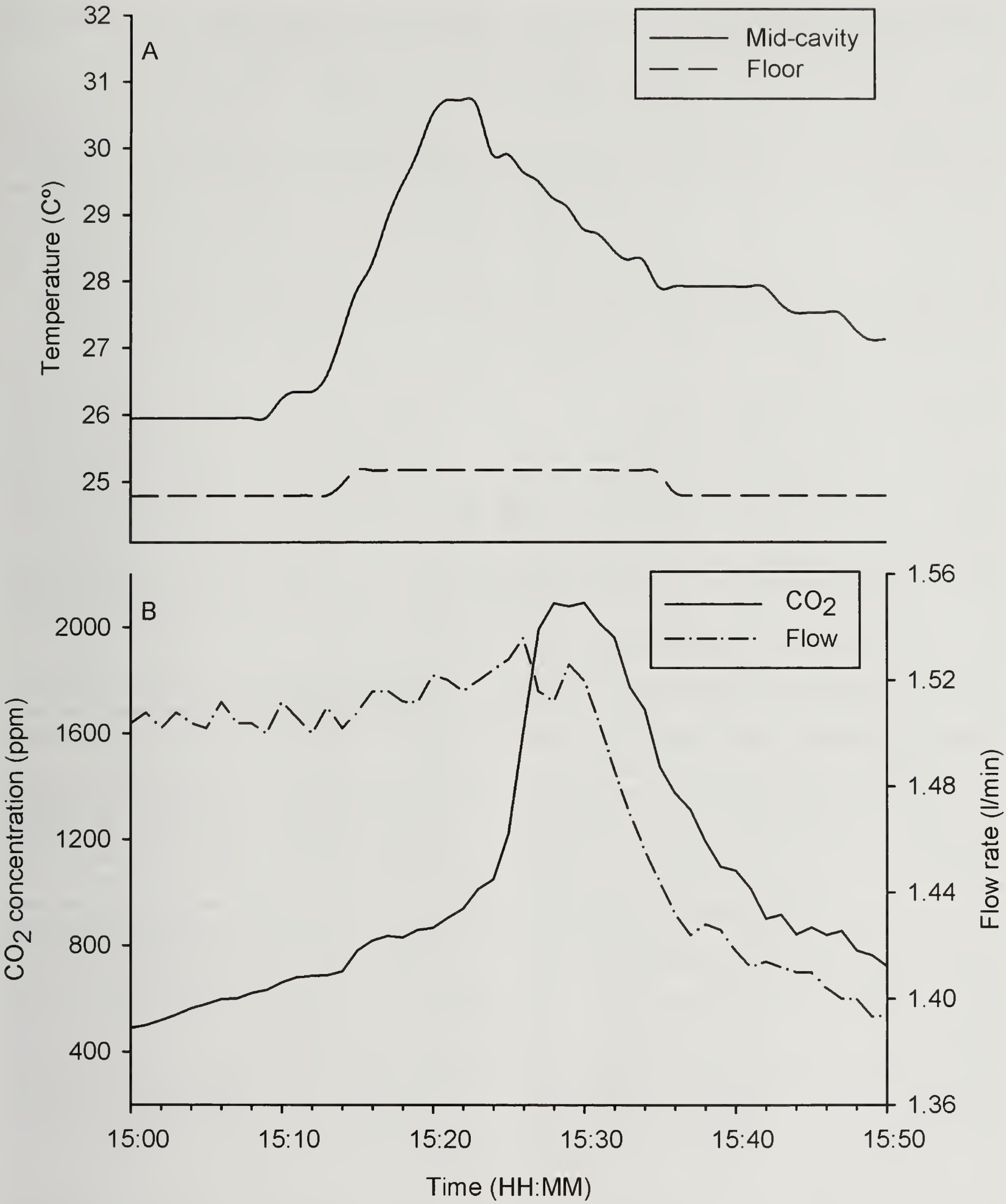

FIG. 2. Ambient conditions inside a Cuban Parrot surrogate nest cavity in Abaco National Park, Great Abaco, Bahamas. (A) Temperatures 30 cm inside the cavity entrance and on the cavity floor 100 cm from the entrance. (B) CO_2 concentration and air flow rate through a particulate filter as a fire passed by the cavity; the flaming front approached the cavity entrance at 15:14 EST and passed at approximately 15:35.

able, the maximum permissible exposure for humans, as determined by the Occupational Safety and Health Administration (1997), is an 8-hr time-weighted average of 5,000 ppm with a short-term (<30 min) exposure limit of 30,000 ppm. Concentrations lower than 15,000 ppm have no detectable effect on people.

Although the tolerance of Cuban Parrots to CO_2 and smoke is unknown, they are capable of surviving fires while nesting. In 2003, a wildfire passed over 20 occupied nests and did not result in decreased fledging success (Stahala 2005). Another wildfire that occurred in ANP in 2005 resulted in a similar lack of mortality (GPM pers. obs.). Our measurements also provide direct evidence that fire-induced elevations in temperature and CO_2 concentration would cause minimal stress. Although we sampled only a single cavity (thus limiting our sphere of inference), our results are likely representative, given the low fuel loads that are typically found in nesting colonies.

Burning while the birds are actively nesting might have a relatively minor impact on conditions inside the cavity. Nonetheless, the threatened status and restricted range of the ground-nesting population, as well as the ample opportunity to set fires outside the breeding season, indicates that setting prescribed fires when cavities are occupied needs to be considered carefully. The timing of a fire appears to be important, as parrot pairs seem to choose new nesting sites in recently burned areas. Although it appears that reduced cover due to fire has no significant effect on predation rates of nesting parrots (Stahala 2005), unburned patches near nests might attract predators in otherwise burned areas. If this were true, creating firebreaks around colonies to protect parrots from fire might lead to increased parrot mortality and would not be justifiable. While the direct effects of fire on conditions inside a nest cavity of Abaco's Cuban Parrots appear negligible, indirect effects of frequent fires are of paramount importance, mainly because they reduce fuel loads and fire intensities and are critical for maintaining pineyard ecosystems.

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